due to Dubois for an independent result, it will yet be gratifying to the present Fellows of the Society to know that the original discovery was made by a countryman and a contemporary of Sir John Herschel.

The University of Chicago:
1895 *October* 22.

Micrometrical Determinations of the Diameters of the Minor Planets Ceres (1), *Pallas* (2), *Juno* (3), *and Vesta* (4), *made with the Filar Micrometer of the* 36*-inch Equatorial of the Lick Observatory, and on the Albedos of those Planets.* By E. E. Barnard.

In *Monthly Notices of the Royal Astronomical Society*, vol. liv. No. 9, I have given a series of micrometer measures of the diameters of the asteroids *Ceres* (1), *Pallas* (2), and *Vesta* (4) made with the great telescope.

These measures have been continued this year, except in the case of *Pallas*, whose greatly increased distance discouraged any measures of it.

I have also secured measures of *Juno* on four nights. The disc of this object, however, was extremely small, and so nearly the size of the spurious disc of a star of the same magnitude that it must for the present, perhaps, be taken as showing only the possible maximum diameter.

I am confident, however, that the real disc was seen, as it seemed to sensibly enlarge with the higher powers.

On each night, while under observation, this asteroid was micrometrically referred to some star near it for motion, so that no mistake was possible in its identification.

Ceres has been running very far south—some 28° of south declination. This has made it rather difficult; but no measures were attempted unless the disc was clearly seen.

The measures were made with 1,000 diameters, except in one or two instances, when 1,500 was used. On one or two occasions 2,600 was also employed. But 1,000 was found more uniformly satisfactory.

For completeness of this paper I have added to these measures my observations of 1894 (including those of *Pallas*).

Micrometrical Measures of the Diameters.

Ceres (1).

		Obsd.	At Δ 2·7673.	δ
1894.		″	″	″
Mar.	12	0·75	0·44	−0·05
	25	0·72	0·43	−0·04
Apr.	1	0·73	0·44	−0·04
	9	0·58	0·36	+0·03
	16	0·60	0·39	0·00
	23	0·59	0·40	−0·01
	30	0·58	0·40	−0·01
May	7	0·47	0·34	+0·05
1895.				
May	12	0·53	0·40	−0·01
	13	0·56	0·42	−0·03
June	2	0·60	0·41	−0·02
	3	0·56	0·39	0·00
	17	0·67	0·45	−0·06
	23	0·47	0·32	+0·07
	24	0·64	0·43	−0·04
	30	0·48	0·32	+0·07
July	1	0·63	0·43	−0·04
	7	0·62	0·43	−0·04
	8	0·48	0·33	+0·06
	14	0·55	0·38	+0·01
	15	0·57	0·40	−0·01
Aug.	4	0·44	0·33	+0·06
	5	0·43	0·32	+0·07
			0·389	

or at Δ1 = 1″·076.

In the measures of *Ceres* in 1894 I have omitted the observation of March 11, as all the other measures show it was too large.

Pallas (2).

		Obsd.	At Δ 2·7673.	δ
1894		″	″	″
Feb.	25	0·75	0·34	−0·10
	26	0·59	0·26	−0·02
Mar.	11	0·44	0·21	+0·03
	12	0·46	0·21	+0·03
	25	0·40	0·20	+0·04
			0·244	

or at Δ1 = 0″·675.

Juno (3).

		Obsd.	At Δ 2·7673.	δ
1895.		″	″	″
July	21	0·16	0·11	−0·02
	22	0·14	0·10	−0·01
Aug.	4	0·12	0·09	0·00
	5	0·11	0·08	+0·01
			0·095	

or at Δ1 = 0″·263.

Vesta (4).

		Obsd.	At Δ 2·7673.	δ
1894.		″	″	″
Mar.	11	0·38	0·23	−0·04
	12	0·46	0·22	−0·03
	25	0·33	0·16	+0·03
Apr.	1	0·39	0·20	−0·01
	9	0·29	0·15	+0·04
1895.				
July	7	0·35	0·19	0·00
	8	0·44	0·24	−0·05
	14	0·41	0·21	−0·02
	15	0·42	0·22	−0·03
	21	0·38	0·19	0·00
	22	0·38	0·19	0·00
Aug.	4	0·40	0·19	0·00
	5	0·42	0·20	−0·01
	11	0·43	0·20	−0·01
	12	0·35	0·17	+0·02
	18	0·43	0·20	−0·01
	19	0·40	0·19	0·00
	25	0·40	0·19	0·00
			0·195	

or at Δ1 = 0″·540.

δ in each case is the deviation from the mean.

No correction has been applied for irradiation, since it is not only an unknown quantity, but must also be inappreciable in these measures. No correction has been applied for phase, because the measures were made at and near opposition, and the correction would be insensible.

Collecting the results, we have for the diameters of

	At Δ 2·7673.	At Δ1.
Ceres	0″·389	1″·076
Pallas	0·244	0·675
Juno	[0·095]	[0·263]
Vesta	0·195	0·540

Reduced to English miles, these become, for

Diameter of Ceres (1) = 485 miles
„ Pallas (2) = 304 „
„ Juno (3) = [118] „
„ Vesta (4) = 243 „

In comparing the measures for the two years, it will be seen that in the main they are perfectly accordant. Those of the present year were not reduced until the close of the work. The observations are therefore free of bias.

These results, I believe, are very accurate, and I think we have now for the first time satisfactory information of the dimensions of at least three of the four brightest asteroids. I feel sure that the diameters of *Ceres*, *Pallas*, and *Vesta* are now as well known as are those of the four bright moons of *Jupiter*.

I hope to take up the measurement of these bodies with more powerful optical means in the near future, and, if possible, extend the list to other members of the asteroidal group. In the winter of 1896 *Juno* will be very favourably placed for measurement, and I shall hope then to get good measures of it.

Previous Efforts to determine the Diameter of these Asteroids.—A friend has called my attention to a recent paper by Mr. H. Sadler, containing a collection of the various previous efforts to determine the diameters of these four asteroids. Mr. Sadler's paper can be found in the *English Mechanic* for August 2, 1895, p. 533.

Because of the importance of the subject, I will copy here the results he gives for previous observations.

Ceres (1).

Schröter (diameter) ...	1,570 miles	Bruno ...	227* miles
Wm. Herschel	162 „	Galle ...	396 „
Argelander	225* „	Knott ...	630 „

Pallas (2).

Schröter	2,025 miles		
Wm. Herschel	122 ,,		
,,	also 83 and 70 miles, "almost incredibly small."		
Lamont ...	667 miles	Bruno ...	171* miles
Argelander ...	158* ,,	Pickering ...	167* ,,

Juno (3).

Schröter ...	1,380 miles	Stone ...	124* miles
Argelander ...	105* ,,	Pickering ...	94* ,,
Bruno ...	115* ,,		

Vesta (4).

Schröter ...	333 miles	Secchi ...	450 ± miles
Mädler ...	290 ,,	Tacchini ...	880 ,,
Argelander ...	270* ,,	Millosevich	630 ,,
Bruno ...	230* ,,	Pickering ...	319* ,,
Stone ...	214* ,,		

The diameters marked with an asterisk (*) were derived by photometric means.

The general agreement of these photometric values is doubtless due to essentially the same data being employed by each of the astronomers.

Mr. Sadler had evidently not seen Dr. G. Müller's elaborate photometric observations of three of these four asteroids—viz. *Ceres*, *Pallas*, and *Vesta*. Dr. Müller's work comprises No. 30 of the Publications of the Astrophysical Observatory of Potsdam, 1893. He deduces the dimensions of these three bodies on two suppositions. First, that their albedo is equal to that of *Mercury*; second, that it is equal to that of *Mars*.

His results are :—

	I. Radius.	II. Radius.
Ceres	475 kilom.	379 kilom.
Pallas	354 ,,	282 ,,
Vesta	473 ,,	377 ,,

These give the following *diameters* in English miles :—

	I.	II.	Means.
Ceres	594 miles	474 miles	534 miles
Pallas	442 ,,	352 ,,	397 ,,
Vesta	591 ,,	471 ,,	531 ,,

The uncertainty of the photometric method in determining the dimensions of these bodies is well shown by the large differences in the results derived by even this moderate range of assumed albedo.

In reality there is a very wide range of albedo among the asteroids themselves—at least as great as that found among the planets.

This is not surprising, for even in so closely related bodies as the four bright moons of *Jupiter*, there is a very great range of albedo.

From my measures it is now possible to determine the albedos of these four asteroids with considerable precision.

Professor Arthur Searle, of the Harvard College Observatory, has kindly supplied me with the photometric magnitudes of *Ceres*, *Pallas*, *Juno*, and *Vesta*, as determined at Harvard College Observatory, and by Mr. H. M. Parkhurst at Brooklyn, N.Y.

These values, reduced to mean opposition and to distance unity, are :—

Ceres.

	At M. Opp. m.	At Δ_1. m.
H.C.O. Merid. Photom. Observers, Pickering and Wendell (15*n*)	7·72	4·27
Brooklyn, N.Y. H. M. Parkhurst	...	3·74
H.C.O. Wedge Photom. Observer, Wendell (16*n*)	7·24	3·84

Pallas.

H.C.O. Merid. Photom. Pickering and Wendell (17*n*)	8·48	5·02
Brooklyn, N.Y. H. M. Parkhurst	...	4·50

Juno.

H.C.O. Merid. Photom. Pickering and Wendell (15*n*)	9·50	6·26
Brooklyn, N.Y. H. M. Parkhurst	...	5·77

Vesta.

H.C.O. Merid. Photom. Pickering, Searle, and Wendell (22*n*)	6·47	3·93
Brooklyn, N.Y. H. M. Parkhurst	...	3·49
H.C.O. Wedge Photom. O. C. Wendell (23*n*) ...	6·79	4·25

Müller's photometric values from the Potsdam observations are :—

	At Δ_1. m.		At Δ_1. m.
Ceres	3·46	Vesta	3·47
Pallas	4·10		

The means of these different determinations are :—

	At $\Delta 1$.		At $\Delta 1$.
	m.		m.
Ceres	3·83	Juno	5·91
Pallas	4·55	Vesta	3·79

It will be seen that these various determinations by different observers differ in some cases by nearly an entire magnitude.

Albedos.—Müller gives the magnitude of Mars = − 1·297. From the above values of the magnitudes I have derived, from my diameters, the following albedos of these four asteroids :—

Albedos (*Mars* = 1·00).

Ceres	0·67	Juno	1·67
Pallas	0·88	Vesta	2·77

Müller has determined the albedos of the various planets, and it is interesting to compare these with the above.

Albedos and Magnitudes of the Planets (*Müller*).

	Albedo.	Mag. at $\Delta 1$.
Mercury	0·64	−0·003
Venus	3·44	−4·004
Mars	1·00	−1·297
Jupiter	2·79	−8·932
Saturn	3·28	−8·685
Uranus	2·73	−6·858
Neptune	2·36	−7·053

By comparison, it will be seen that the surface of *Ceres* reflects light with about the same intensity as that of *Mercury*, *Pallas* somewhat less than *Mars*, *Juno* between that of *Mars* and *Jupiter*, while *Vesta* is about equal to that of *Jupiter*.

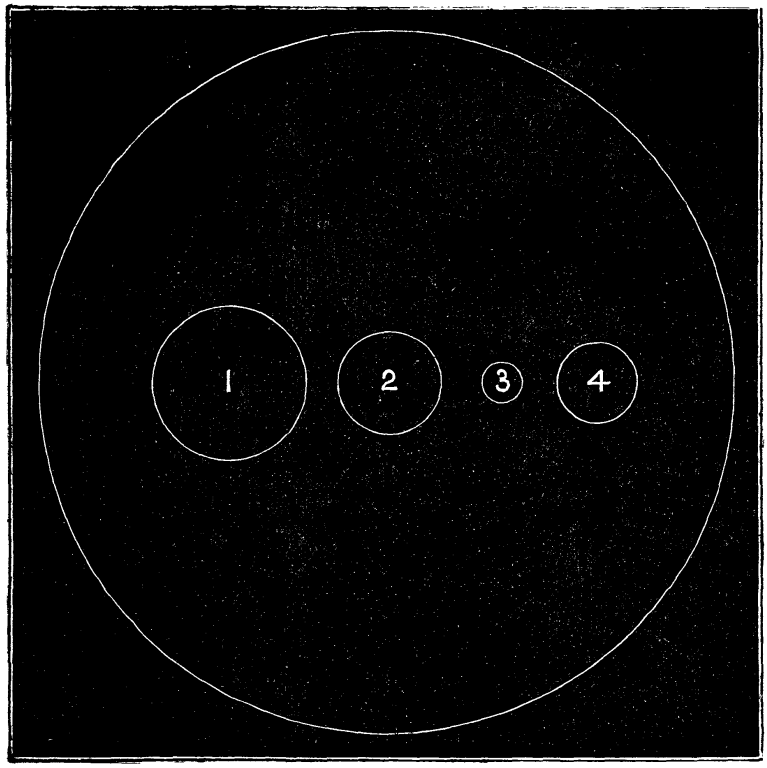
The mean albedo of the four is 1·45. This value will be a far safer standard to use in the determinations of the dimensions of the other asteroids by photometric methods than that previously adopted.

Up to the making of these measures with the 36-inch, *Vesta* was considered, from its generally greater brightness, to be the largest of the asteroids. It is now understood, from its high albedo, why it was so bright. Its surface reflects light with four times the intensity of that of *Ceres*.

It will also be readily seen that *Ceres* is really by far the largest of the asteroids.

In conclusion, I think it is scarcely necessary to add that all previous attempts at direct measures of the diameters of these small bodies were made with instruments inadequate to deal satisfactorily with such minute quantities as the asteroidal

diameters. They are far more difficult to deal with than the four bright moons of *Jupiter*.



Relative sizes of the four bright asteroids and the Moon (the inclosing circle is the Moon).

To make the relative sizes of these four asteroids apparent at once to the eye, I give a diagram made from my measures.

Professor Tucker, of the Lick Observatory, kindly and specially observed the magnitudes of these four asteroids for me with the meridian circle of the Lick Observatory. It was my intention to incorporate these visual magnitudes with the photometric values in deducing the albedos of *Ceres*, *Pallas*, *Juno*, and *Vesta*; but I finally decided to use the photometric results alone, as the albedos of the planets had been so determined by Dr. Müller. Professor Tucker's great experience in estimating magnitudes in his valuable work in observing the Cordoba D.M. will make these estimations valuable.

I herewith append his results.

Estimations of the Magnitudes of Ceres, Pallas, Juno, and Vesta.
By R. H. Tucker, Jun., 1895.

1895 July 26	Ceres	8 mag.		1895 July 31	Pallas	$8\frac{1}{4}$ mag.
26	Juno	$8\frac{1}{4}$ mag.		31	Vesta	$6\frac{3}{4}$ mag.

These are the observed magnitudes, and will be on the same scale as those of the Cordoba D.M.

Mount Hamilton, California:
1895 *August* 29.

On the Extended Nebulosity about 15 *Monocerotis.*

By E. E. Barnard.

I am somewhat surprised at Dr. Roberts' statements in *Monthly Notices*, vol. lv. No. 7, for May 1895, where he condemns the idea of the diffused nebulosity shown about 15 *Monocerotis* on my photograph of 1894 February 1.

I must also object to the unjust comparison that he has made. He has shown upon the screen a lantern slide made from my glass positive of this region, which is in the possession of the R.A.S. This he has enlarged some four or five times to compare with his *unenlarged* photograph. He finds under these conditions that my picture is coarse, and that the nebulosity to which I called attention is not real, but is due to diffused light from many small stars.

I would say that these pictures, made with a short focus lens, are not intended to be enlarged, or, if so, but slightly. If the subjects are wanted on a larger scale the best plan is to use a longer focus and bigger telescope for that purpose—such, for instance, as Dr. Roberts' reflector.

They are intended to be looked at and studied as *pictures* of the regions they show, and are not to be examined microscopically. It is unjust to use an enlargement such as Dr. Roberts used, because it necessarily puts these pictures at a disadvantage. My picture was simply spoiled by this, while Dr. Roberts retained its original qualities, not being enlarged.

An enlargement should not be made from a copy, but from the original, because a copy like this was made with special reference to showing the nebulosity; the stars therefore suffer, especially if an enlargement is made.

A short focus lens like this is not intended to show small details because of its small scale. The study of small details belongs specially to large telescopes. The short focus lens, however, is exceptionally fine for just such large diffused nebulosities as that surrounding 15 *Monocerotis.*

Dr. Roberts seems to forget, in speaking of my paper in *Astronomy and Astro-Physics*, vol. xiii. pp. 178–182, that it was I who called his attention to the fact that 15 *Monocerotis* was really nebulous, and that the closer nebulosities about this star were the special province of larger telescopes than mine.

I shall quote from the article in *Astronomy and Astro-Physics*:—